REMARKS

Rejections Under 35 U.S.C. §102

Claims 1-4, 6-8 and 10 are rejected under 35 U.S.C. 102(b) as being anticipated by Yitzhaky et al "Identification of Motion Blur for Blind Image Restoration".

Applicant disagrees with the Examiner's assertion that the article describes the image processing technique claimed in the present application. Specific arguments drawn to each claim will be presented later in this amendment. First, a summary of the differences between the techniques and their applications will be provided as background information and to better clarify later arguments to the specific claim rejections

Both methods attempt to remove the blur from a degraded image. The Yitzhaky method only applies to an image with a one-dimensional motion blur. This type of blur occurs if one moves a camera horizontally during the exposure time. The image is smeared only in that direction. Building on research by previous authors, Yitzhaky estimates the length of the blur (how many pixels the blur covers) by measuring artifacts in an image that results from a series of mathematical operations. Once the size of the blur in that direction is calculated, Yitzhaky synthetically recreates the blur function and suggests a filter that will

remove the blur from the image. The Yitzhaky method cannot be used on any other type of blur.

The Self-Deconvolving Data Reconstruction Algorithm Method (SeDDaRA method) of the present invention is not at all limited to one-dimensional motion blur. It has been demonstrated on blurs caused by two-dimensional motion, focusing error, defects in the optics, atmospheric effects (for telescopes), and non-optical images such as x-rays and ultrasound scans. The technique accomplishes this task with distinctly different approach and theory than Yitzhaky. This method relies on a general statement that many scenes or signals contain similar frequency characteristics.

As with sound, images can be represented by frequencies. A blurry image has reduced high frequencies, *e.g.* sharp edges appear smooth and small objects disappear. With SeDDaRA, the frequency spectrum of a similar, but sharp, image can then be used to amplify the degraded frequencies in the blurry image. The closer the scenes are in frequency content, the better the restoration will be.

These frequencies can be accessed directly through the application of Fourier transform. The transform reveals the frequencies of the image and their placement. A Fourier transform applied to an orchestra recording would reveal how many instruments were playing each note and octave of the scale. The result of the transform has two components, magnitude and phase. The

magnitude contains information about what frequencies exists in the image, lower frequencies are registered near the center of the image. The phase describes the location of the frequencies in the image. Neither looks anything like the original image. If an *inverse* Fourier transform is applied to these components, the original image will be reproduced. The Fourier transform is demonstrated in Figure 1.

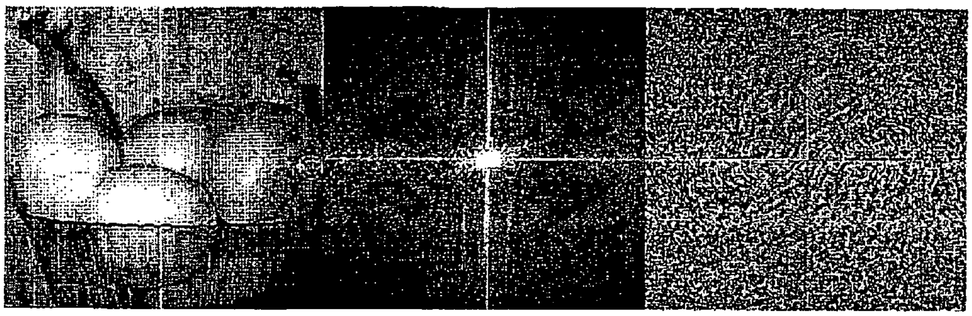

Figure 1: (Left) An image of a bowl of fruit. (Center) The magnitude component of the Fourier transform of the image. This image provides information about the frequency distribution in the image. (Right) This is the phase component of the Fourier transform. This image provides information about the relative position of the frequencies in the image.

The advantage of a Fourier transform is that we can directly manipulate the frequencies of the image without disturbing the phase (how those frequencies are distributed). If the high frequencies are boosted, edges will become sharper. This can be accomplished using the point spread function (PSF) and the Wiener filter.

The PSF can be thought of in terms of taking a picture of a star. Ideally, the light from the star falls on a single point in the image. However, if the camera is out of focus, the star will appear blurry, and light will fall on a small area instead. When we take a picture, we would rather have each point in the image look like the in-focus star, rather the blurry one. The blurry image of the star can be used as a PSF. The Fourier transform of the star is called the optical transfer function, or OTF. In Fourier space, if we divide the image frequencies by the OTF, and inverse transform the result back into an image, we would have removed the blur from the image.

This division normally does not work well with real images. Instead a Wiener filter is used. It is very close to the division but shields us against dividing by very small numbers. The Wiener filter is described in detail in the technical portion of the patent.

So a general process for cleaning up a blurry image is to identify the PSF, apply a Fourier transform to the images, apply the Wiener filter, and then apply the inverse Fourier transform to get the reconstructed image back. The trick here is identifying the PSF, which is the main purpose of the applicant's method, and the primary difference between the patent application and the Yitzhaky paper.

For the claimed process, the entire PSF is extracted from the blurry image. This is accomplished by first applying a Fourier transform to the image. We want the frequencies of the blurry image to look like the frequencies of a non-blurry image, so a mathematical operation is applied to the frequency spectrum of the blurry image. The operation is described by the power law equation (7) and displayed here.

$$D(u,v) = K_D S\{[G(u,v) - W(u,v)]^{\alpha}\}$$

The 'α' exponent reshapes the frequencies of the image to estimate the OTF in Fourier space. This formula is the basis for the inventive method claimed in the patent and is not disclosed or made obvious in any way in the Yitzhaky paper.

The α function can be described in several ways. The easiest method is to choose a number between 0 and 1 (This is for images, the range between -1 and 1 is used for signals.). Here we are saying that the function is independent of frequency, i.e. that the non-blurry image contains all frequencies equally. A second method is to impose a known frequency spectrum onto α so that this function also depends on the variables (u,v). The third, and most used approach is to take a similar, but not blurry, image and use its frequency spectrum for comparison. This is described by equation 18 in the technical patent application.

The non-blurry image does not have to be of the same object as the blurry image. For example, if you have a blurry image of a house, you can use a non-blurry image of another house to estimate the PSF using this technique. You

want to see the sharp corners and edges of the blurry image that you see on the non-blurry image. These are the higher frequencies that get diminished when the image is not taken in focus. The operation of smoothing the estimate of the OTF means that you do not even need a picture of a house. You can try using a good picture of toy blocks, or any image with sharp edges.

Once the PSF has been extracted, you can use many methods for 'deconvolution', however the Wiener filter works well.

Yitzhaky shows how to derive the PSF of a motion-blurred image in a single direction. This is a small subset of types of blur that SeDDaRA can deal with. In his paper, Yitzhaky starts out describing the Wiener filter in section 2. This section is used as a basis for many of the arguements. The filter is not novel for this paper, nor is it being claimed as new in the patent. He states that if you intentionally use the wrong PSF in the Wiener, you get an image with 'shadows'; similar to ghost images you may have seen on old televisions. You can then measure the distance between the ghost image and the original, in pixels, to estimate how big the PSF should be.

In the next section, Yitzhaky proposes a modification to the technique by taking the first derivative of the image. This sharpens the edges of the ghosts. He then performs another operation called an autocorrelation to produce the graph in Figure 2. From this graph you can easily measure the length of the PSF. Once

you have the length, you must construct the PSF. Yitzhaky does not explain how exactly this is done. One assumes you add a short line to a blank image. This PSF is then inserted into the Wiener filter as described in page four, column one.

An actual result is discussed in Section 4. Here the author states that he used a constant value g = 0.05 in the Wiener filter (described as in the patent as 'K'). This is not the same constant α used in the SeDDaRA formula and discussed above.

So in brief, Yitzhaky measures the length of a one-dimensional blur by creating artifacts in the image. In contrast, the SeDDaRA method compares the frequencies of a degraded image to a known constant, or the frequencies of a non-blurred image, to determine which frequencies have been degraded. This process creates a two-dimensional PSF that can be used with any blur.

As specifically regards claim 1, Yitzhaky does not create a filter function from his set of operations. His filter function is synthetically created only after he has measured the number of pixels between the ghost images. Yitzhaky does not apply a power law function to the Fourier transform of the original image. Yitzhaky does not identify the entire system degradation. His method can only identify the motion blur in a single direction.

As for claim 2, Yitzhaky does not describe the discarding of phase information. Yitzhaky is describing the Wiener filter that is used only after the blur function has been identified. The Wiener function does not alter phase information, and this information is not discarded. The information is necessary for adequate restoration. For the SeDDaRA method phase information is discarded when estimating the PSF.

Regarding claims 3 and 4, Yitzhaky does not mention the application of a smoothing function. Yitzhaky does apply a false PSF to the image to produce a shadow image, but this is not considered a smoothing function and is applied completely different reasons. The false PSF is applied to create an artifact in the image that gives information about the length of the motion-blur. The smoothing function in the patent is applied to smooth out small ripples of frequencies. This operation makes it easier to use the frequencies of a different image in place of the actual image.

As for claim 6, Yitzhaky does not use the filter function of Claim 1. Yitzhaky uses a filter function from a completely different method to restore an image.

Regarding claims 7 and 8, Yitzhaky does not use a power law anywhere in his paper. The constant described on Page 4, column 2, line 1, is only used in the Wiener filter and not part of a power law application. On Page 4, column 1, lines

4-9, Yitzhaky reminds us that an estimated PSF can be inserted into the Wiener filter to restore the image. A power law relationship is not discussed here.

As for claim 10, Yitzhaky does not apply the method of claim 1 to signals, images, or multi-dimensional images. The method described by Yitzhaky is not the same method used for SeDDaRA.

Rejections Under 35 U.S.C. §103

Claims 5, 11 and 12 are rejected under 35 U.S. C. 103 (a) as being unpatentable over Yitzhaky et al "Identification of Motion Blur for Blind Image Restoration".

Inasmuch as claims 5, 11, and 12 are all dependent claims that depend either directly, or indirectly, from independent claim 1. For all of the reasons given above, the Yitzhaky reference fails to make the subject matter set forth in claims 5, 11, and 12 obvious. Additionally, the rejection of claim 5 as obvious over Yitzhaky is objected to because the steps Yitzhaky takes to estimate his PSF are not similar to the steps taken in the patent application. Thus it cannot be deduce that the steps in the patent application are interchangeable based on the steps taken by Yitzhaky. In many image-processing techniques, the order of operation is critical to the success of the algorithm.

Objections to the Claims

Claim 9 is objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Claim 9 has been rewritten in independent form including all of the limitations of the base claim and any intervening claims, and is, therefore, allowable.

Conclusion

All the rejections of the claims have been addressed through the amendments and remarks above. For the foregoing reasons, all the claims now pending in the present application are believed to be allowable, and the present application is believed to be in condition for allowance. Accordingly, favorable reconsideration of the application in light of the amendment and remarks is respectfully requested.

If the Examiner has any comments or suggestions that could place this application in even better form, the Examiner is requested to telephone the undersigned representative at the number listed below. Applicant appreciates the Examiners time and efforts.

Respectfully submitted,

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